

EXTENSION OF LINK AGGREGATION PROTOCOLS OVER THE NETWORK

5 Field of the Invention

[0001] This invention is directed to a communication network, and more specifically to a method of connecting devices implementing a Link Aggregation Protocol (LAP) over a Metropolitan Area Network (MAN).

10 Background of the Invention

[0002] A Metropolitan Area Network (MAN) is a communications facility allowing a number of devices to communicate with each other and generally includes workstations, interface components, connecting cables and/or fiber optics, and software for controlling the access and flow of information over the network. The MAN extends, as the name suggests, over a geographical area of a large city and uses, for example, switched Ethernet, ATM or POS as the communication protocol. The typical data rates used by MAN have increased lately from 100Mbps to 1Gbps and even to 10 Gbps, and new transmission protocols are under construction as specified within, for example, the IEEE 802.3 standard.

[0003] Ethernet started as a connectionless local area network (LAN) technology designed for data applications in which all stations on the network share the communication medium. The medium is shared in a peer-to-peer fashion and all devices can be reached by a single data transmission using an Ethernet frame. The protocol data unit for Ethernet is a variable length frame with a 48-bit media access control (MAC) address.

[0004] Common carrier communication links typically include relatively low speed twisted pair communication links like T1 in North America, providing a maximum data rate of 1.544 Mps, or E1 available in Europe at 2.048 Mps. High speed optical based communication links like T3 provide a maximum data rate of 45 Mps, while E3 provides 34 Mps. Networks requiring an intermediate level bandwidth, e.g. 10 to 20 Mps, must use the high speed T3/E3 carrier. This unnecessarily increases the cost of communication as the subscription rate for

T3/E3 is much higher than for T1/E1, the subscriber being compelled to pay for unused bandwidth. In addition, high-speed T3/E3 links are not widely available.

[0005] It has become evident that the shared bus architecture is insufficient to meet the demands of applications that require large bandwidth, and that MANs are beginning to become a bottleneck for the modern telecommunication networks. Thus, switched Ethernet technology was developed to provide more capacity to the end-user. Rather than relying on a shared medium, this technology provides point-to-point bandwidth between the user station and the switch, so that instead of sharing, for example a 100Mbps connection, the user gets a dedicated 100Mbps connection.

[0006] The carrier sense multiple access with collision detection (CSMA/CD) standard defines data encapsulation / decapsulation, and media access management functions performed by the MAC sublayer. A link aggregation protocol/s (LAP), such as the LAP proposed by IEEE 802.3ad, allows one or more links to be aggregated together to form a link aggregation group, such that a MAC Client can treat the group as if it were a single link. To this end, it specifies the establishment of terminal-to-terminal logical links, consisting of parallel instances of point-to-point physical links operating at the same data rate. See "CSMA/CD Access Method and Physical Layer Specifications, IEEE Std 802.3ad-2000, Aggregation of Multiple Link Segments", March, 2000, the content of which is incorporated herein by reference.

[0007] This point-to-point architecture has some disadvantages when the end users are located far apart. Namely, in most such cases a new physical connection needs to be established, since it is not normally easy to provision this connection over an arbitrary MAN mesh. As a result, two IEEE 802.3ad devices are generally directly connected by physical point-to-point links. This also holds true in the case of a fault in the network, where it is not easy to route the point-to-point traffic on an alternative route.

[0008] Accordingly, there is a need to provide a more flexible way of connecting two end users across a MAN.

[0009] Inverse Multiplexing for ATM (IMA) is a method for providing modular bandwidth for users accessing an ATM network, as well as for connecting ATM network elements at rates between the T1/E1 and T3/E3 levels. Asynchronous transfer mode (ATM) is a high-speed connection oriented cell-switched communications technology. Amongst other information, the ATM header contains a virtual path identifier (VPI) and a virtual channel identifier (VCI), which together form a Virtual Circuit. All the cells of a Virtual Circuit (i.e. cells having the same VPI and VCI) follow the same path through the network. This path is determined during the call set-up procedures or by assignment.

10 [0010] IMA combines several physical links to collectively make up an IMA group arranged as an IMA virtual path between two specified devices. See for example the ATM Forum, "Inverse Multiplexing for ATM (IMA) Specification", Version1.1, March, 1999, the contents of which are incorporated herein by reference. The ATM inverse multiplexing (IMA) provides an effective method for 15 combining multiple T1/E1 links selected to collectively provide higher intermediate rates on logical links.

[0011] Again, the IMA group is comprised of dedicated logical links connecting two specified devices. However, this protocol is specifically designed for ATM cells and can not be applied as such to Ethernet frames.

20 [0012] Accordingly, there is a need to provide multiple, controllable connections over the network between any two devices capable of implementing link aggregation protocols (LAP), by provisioning, without dedicating, logical links over the MAN.

25 Summary of the Invention

[0013] The present invention seeks to overcome the disadvantages of the prior art associated with the connectivity of devices implementing LAPs over a MAN.

[0014] According to one aspect of the invention, a method for extending a LAP between a first data terminal and a second data terminal physically connected over a communication network is provided. The method comprises receiving a request to establish a connection between the data terminals, the 5 connection being defined by specific traffic parameters; detecting a plurality of maximally disjoint paths between the data terminals; and establishing the connection over two or more logical links along a respective two or more maximum disjoint paths.

[0015] According to another aspect of the invention, a switching node of a 10 communication network for routing traffic between a near end and a far end data terminals, is provided. The switching node comprises a plurality of input ports and output ports, each port having specified traffic parameters; a link aggregation interface for assigning an input port and a corresponding output port to a physical route between the near end and the far end data terminals under supervision of a 15 node controller; and a switch for routing traffic between the input port and the corresponding output port according to a connectivity map and establishing communication between the near end and the far end data terminals along a logical link.

[0016] According to yet another aspect of the invention, multiple logical 20 links may be created to connect network devices implementing a LAP. An efficient provisioning of bandwidth is obtained in physical link increments, while avoiding use of the costly high speed carriers. Advantageously, the extension of LAPs over the network provides increased availability because a network failure can now be propagated to the edge of the network to allow the edge LAP devices 25 to quickly react to the failure. A failure at the edge of the network is also propagated to the other edge allowing that edge device to react to the far edge failure.

[0017] The "Summary of the Invention" does not necessarily disclose all 30 the inventive features. The invention may reside in a sub-combination of the disclosed features.

Brief Description of the Drawings

[0018] The invention will be now explained by way of example only and with reference to the following drawings:

5 [0019] **Figure 1A** illustrates the OSI reference model for an access network using a link aggregation sub-layer;

[0020] **Figure 1B** shows a point-to-point connection for the current LAPs;

[0021] **Figure 2A** is a an illustration of multiplexing / demultiplexing of ATM cells over inverse multiplexed links;

10 [0022] **Figure 2B** illustrates the delays of various links aggregated as in Figure 2A;

[0023] **Figure 3** illustrates two devices implementing a LAP according to the invention;

[0024] **Figure 4A** is a diagram showing alternative logical links provisioned over the network between two network devices;

15 [0025] **Figure 4B** is a block diagram of a node of network shown in Figure 4A; and

[0026] **Figure 5** is a flow chart for illustrating the LAP according to the invention.

20 [0027] Similar references are used in different figures to denote similar components.

Detailed Description

25 [0028] The following description is of a preferred embodiment by way of example only and without limitation to combination of features necessary for carrying the invention into effect.

30 [0029] A network architecture defines protocols, message formats, and other standards to which all the devices and software must adhere. Functional network layers are established within a network architecture, each layer for performing a specific set of functions and a specific set of services. Protocols define the services covered across a layer interface, as well as the rules followed for performing that service.

[0030] Figure 1A illustrates the OSI reference model, for an access network using a link aggregation sub-layer.

[0031] The International Standards Organization (ISO) proposes a seven layer reference model for computer networking, which are still used to design standards for the communication networks architecture. Only link layer **2** is of relevance to this invention. Thus, the network, transport, session presentation, and application layers are not discussed, as they are not relevant to this invention. The physical layer **1** can be any of optical fiber, twisted pair, coaxial cable, wireless.

10 [0032] The MAC sub-layer **3**, the MAC control sub-layer **4**, and the MAC Client **6** are known as the data sub-link layers. In the case of traffic ramping-on an Ethernet network, these sub-layers are responsible for assembling the data received from the upper layers into frames and providing the frame with a Media Access Control (MAC) address. For the traffic ramping-off the Ethernet network, these sub-layers are responsible with extracting data from the incoming frames.

15 [0033] The IEEE 802.3ad protocol defines the specific requirements for LANs and MANs to perform aggregation of multiple link segments. These networks are provided with a link aggregation sub-layer **5** which allows one or more links, having same traffic characteristics (e.g. same bandwidth and delay) to be aggregated together to form a Link Aggregation Group (LAG) such that the MAC Client sub-layer **7** can treat the LAG as a single link.

20 [0034] Link Aggregation Control (LAC) is a function which configures and controls the link aggregation sub-layer **5**. A "physical link" is defined as the physical connection medium between two successive data terminals of the access network. The LAC function determines the physical links that may be aggregated, enables a distributor and/or a collector to aggregate physical links into a logical link, assigns to, or detaches ports from the aggregator, and continuously monitors the aggregation to determine when changes are needed.

25 [0035] Physical links are aggregated according to the operational keys of the end ports, which reflect, for example, port rate, duplexity, type of traffic, and various administrative constraints. One of the two terminals is designated as

the “controlling system” for avoiding overlapping activities, i.e. if both terminals would be able to change operational keys this can create confusion.

[0036] The Link Aggregation Control Protocol (LACP) used by LAC sub-layer **5** automatically executes the LAC functions using peer exchanges across 5 the respective logical links to determine and implement aggregation, and provides the maximum level of aggregation capability achievable. The configuration mechanism continuously monitors for changes in the physical link state that require reconfiguration and corrects a mis-configuration by performing re-configuration and/or by taking mis-configured links out of service. The 10 configuration achieved is made independent of the order in which events occur, and is determined by the combination capabilities of the individual links based exclusively on their physical characteristics.

[0037] As shown in Figure 1B this link aggregation protocol requires the devices **8** and **9** to be directly connected by physical point-to-point (p2p) links **10-1**, **10-2** and **10-3**.

[0038] Figure 2A shows another type of link aggregation, known as inverse multiplexing for ATM (asynchronous transfer mode) IMA. IMA provides modular bandwidth for user access to an ATM network and for connection between devices into the network at rates between the traditional rates. As 20 shown, several physical links **13-1** to **13-N** are combined into an IMA group **G** arranged as an IMA virtual path **14** between two specified devices provided with IMA interfaces **11** and **12**. For clarity, the virtual path **14** is a suggested representation of the IMA group **G**.

[0039] The IMA protocol operates on interfaces running at the same 25 nominal Link Cell Rate (LCR) and implies the creation of an IMA specific Transmission Convergence (TC) layer positioned between the physical layer and the ATM layer (not shown). At the near end (NE) interface **11**, a single ATM flow is converted at network element **8** into multiple ATM streams by distributing the ATM cells across “N” links in a cyclic round-robin sequence, and a cell-by-cell 30 fashion, according to a transmission direction. At the far end (FE) interface **12**, the cells arriving on individual links **13-1** to **13-N** are re-combined according to a

receiving direction to retrieve cells using a similar cyclic round-robin sequence and cell-by-cell basis. Thus, the original ATM flow is recovered, while compensating for the delays shown for example in Figure 2B. In any event, all cells transmitted by NE device **8** are carried by the IMA virtual path **14** at the FE device **9**, and the cells shall only be terminated by the FE interface **12** located at the far end of the virtual path **14**. Lastly, the re-assembled ATM flow is sent to an ATM layer.

5 [0040] However, as indicated above, this type of link aggregation is designed for ATM cells, which have a fixed length, and thus the delays can be
10 controlled and handled accordingly.

15 [0041] The present invention is concerned with a method that allows extension of the current point-to-point Ethernet LAP to operate across a communications network. The principle of operation of the present invention is shown in Figure 3. In the following description, the term 'end-to-end logical link' refers to a connection between two data terminals equipped with a link aggregation interface according to the invention. An end-to-end logical link is made-up of a plurality of successive physical links between the nodes of a network **20**, the physical links having varying operational parameters, such as bandwidth, delay, administrative costs, etc.

20 [0042] The idea is to provision multiple connections between any two data terminals **8** and **9** over the network **20** by creating end-to-end logical links as shown at **15-1** to **15-3** by way of example. Data terminals **8**, **9** are in this case, for example, Ethernet devices provided with link aggregation interfaces **16** and respectively **18**, as will be shown in further detail in connection with Figures 4A
25 and 4B. The logical links **15-1** to **15-3** provide the virtual point to point connectivity which the data terminals normally expect.

30 [0043] The logical links are so selected so as to be maximally disjoint, and have similar characteristics (bandwidth, delay, administrative cost, etc) using a multi constraint and maximally disjoint path algorithm. The maximum disjoint path algorithm is based on a modified Dijkstra-type algorithm, and allows

selection of a plurality of alternative end-to-end physical routes between the data terminals, the routes sharing a minimum number of nodes and physical links.

[0044] Such an algorithm is described in a patent application entitled: "Method and Apparatus for Selecting Multiple Paths Taking Into Account Shared

5 Risk", Pieda et al., assigned to the same assignee, filed concurrently herewith and incorporated herein by reference. In this application, methods, systems and computer readable media are provided which facilitate the selection of multiple paths through a network represented by a network topology which take into account shared risk which may exist between network resources. The method 10 involves identifying a first path through the network topology from a source node to a destination node, the first path comprising a first sequence of network resources. For at least one shared risk group, a determination is made if any of the at least one shared risk group includes any of the first sequence of network resources, a shared risk group being a group of network resources within the 15 network topology which have a shared risk. A topology transformation is performed of the network topology into a virtual topology which discourages the use of network resources in any shared risk group determined. A second path through the virtual topology is identified from the source node to the destination. The method may be adapted to encourage node and/or edge disjointness.

20 [0045] To summarize, network **20** is a "smart network", comprising dynamically re-configurable switches and is capable of monitoring, correcting and reserving end-to-end physical routes after the access ports to be connected and the traffic parameters are set. Once the physical routes are established, network **20** monitors the logical links and takes appropriate action/s upon any network 25 significant event.

[0046] Figure 4A is a diagram showing alternative logical links provisioned over the "smart" network **20** comprising a plurality of nodes **C**, **D**, **E**, **G**, **H**, **K**, **P**, **M**, and **N**. In this example, data devices **A** and **B** are connected to end nodes, or edge nodes **C** and **N** respectively, to provide communication between terminals 30 **A** and **B** over network **20**. When a request for an A-B connection is received by network **20**, network **20** detects a plurality of physical routes using the maximally

disjoint path algorithm. The network then selects a number of logical links that in combination can satisfy the operational parameters of the connection provided in the request, and allocates corresponding ports to logical links. If, for instance, the logical links that perform as requested by the **A-B** connection are logical links

5 **10-1, 10-2, and 10-3**; and if, for instance, switching node **23** has input ports **a, b** and **c** and node **27** has output ports **k, l** and **m** allocated to the requested connection; then the ports that communicate along the same logical link, such as for example input port **a** and corresponding output port **l** communicating over logical link **15-1**, must have paired operational parameters.

10 [0047] If a failure occurs in the network, as shown at **21** on the span between nodes **H** and **L**, the network **20** quickly reacts to this event. However, the data terminals **A** and **B** are not directly connected to the ends of the failed span **H-L**, so that they are unaware of the failure. According to the invention, the information regarding the failure **21** inside the network **20** is propagated towards 15 the edge nodes **C** and **N** where the data devices **A** and **B** are connected. A failure at the edge, port **a, b** or **c** at edge node **C**, is also propagated to the far edge node **N** ports **k,l** or **m**.

15 [0048] Figure 4B shows a block diagram of a switching node **23** of network **20**, equipped with a link aggregation interface **34** according to the invention. Figure 4B shows only the blocks of the node that are relevant to the invention. A node **23** is generally equipped with a switch **31** for routing the traffic from the input ports **31** to the output ports **32**, according to a connectivity map **33**, as instructed by a node controller **35**. Figure 4B also shows the link aggregation interface **16'** corresponding to interface **16** on the data device **A**. Link aggregation interface **16'** is responsible for maintaining a list of logical links which are being used by this invention. This information is provided by the node controller **35** in conjunction with the other nodes of network **20**. Also illustrated at node **23** is a fault detection and communication block **34** that is used to determine a fault in an input signal and to provide this information with the output signal. It is to be noted that block **34** illustrates the detection and communication of a fault intuitively; the actual implementation of this functionality is not the object

of the invention. The idea is that in general, the nodes at the ends of a failed span have means for detecting and communicating that a fault occurred. Once this information becomes available at node **23**, block **34** propagates this information to edge nodes **C** and **N** over network **20**. A similar fault detection 5 and fault communication mechanism exists on the internal nodes. This mechanism allows the faults on internal network links to be propagated to the edge nodes **C** and **N**.

[0049] Figure 5 is a flow chart illustrating the extending LAP according to the invention. At step **51** a request for connecting two data devices **A** and **B** is 10 received. The request also comprises the operational parameters regarding the connection, such as the bandwidth, delay, administrative costs, etc. At step **52**, the network identifies the maximally disjoint paths (routes) that connect edge nodes **23** and **27** where devices **A** and **B** are connected to the network. The routes are, as indicated above, connected by a succession of compatible 15 physical links. In step **53**, network **20** selects logical links between the end-points **C** and **D** that may satisfy, in aggregation, the request received in step **51**. If the logical links are able to satisfy the request, shown at YES on decision block **54**, the list of logical links are grouped by interfaces **16'** at each node to allow the fault mechanism to communicate any failures of any of the physical links which 20 make up the logical links. communication along these logical links is now possible and the edge devices **A** and **B** can now pass data, step **57**. If the operation of selecting the logical links is not successful, the network operator is informed in step **55**, and the aggregation is ended, step **56**.

[0050] The present invention also provides for a failure propagation 25 mechanism to support extension of LAP. As discussed above, in an arbitrary MAN mesh, it is not easy to provision physical links for connecting network devices. The faults are detected as shown in step **58** which shows that network **20** continuously exchanges peer information to determine the link state. If a failure is detected inside or at the edge of network **20**, step **60**, this information is 30 propagated to the edges (internal link failure) or far edge (edge failure) of the network **20** where the user equipment **A** and **B** is attached, step **61**. The

respective edge aggregation ports **a**, **b** or **c** on switching node **C**, and **k**, **l** or **m** on switching node **N** are forced into a disabled state, so that the user equipment can detect that a link is down and rapidly react to this condition, by re-distributing the flow from the failed logical link onto the remaining logical links.

5 [0051] If no failure is detected in step **60**, the operation of the logical link continues until a request to terminate the service is received in step **62**, when the logical link is released. If not, the communication along the logical link continues as shown by branch NO of decision block **62**.

10 [0052] The proposed link recovery is fast and allows rapid restoration through alternative route/s selection. The user equipment does not have to wait until the conventional link aggregation - link state protocol detects a timeout condition, generally one second. The conventional mechanism is much slower and may result in the loss of a large amount of data.

15 [0053] Numerous modifications, variations, and adaptations may be made to the particular embodiments of the invention without departing from the scope of the invention which is defined in the claims.